NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2084

STRENGTH PROPERTIES OF RAYON-MAT HONEYCOMB CORE MATERIALS

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SUMMARY

An investigation was made to determine some of the strength and elastic properties of honeycomb-type core materials fabricated from resin-impregnated rayon-mat fabrics. Eight blocks of core material were made at the Forest Products Laboratory by the corrugation method, using both 30- and 45-pound rayon-mat fabrics. Cores were made with each of the above fabrics corrugated either parallel or perpendicular to the preferred direction of the individual fibers of the mat and with the contact resin content of each core approximately either 70 or 20 percent of the total weight of the finished core.

The tensile strength of the higher-resin-content, 45-pound rayon-mat cores having the fiber direction parallel to the axes of the cells was approximately 40 percent greater than the strength of paper honeycomb core material of equal density having the fiber direction perpendicular to the axes of the cells. However, the compressive strength, modulus of elasticity, shear strength, and modulus of rigidity of the rayon honeycomb were approximately one-half of the values for the corresponding properties of the paper honeycomb. Considerably reduced strength values in compression and shear were obtained from tests of the rayon cores of lower resin content. The tensile strength of the cores having a contact resin content of 20 percent was higher on a specific strength basis than that of the cores having a contact resin content of 70 percent. Cores with the fiber direction perpendicular to the axes of the cells had lower tensile and compressive strengths, but higher shear strength, than the cores having parallel fiber orientation.

Honeycomb core materials fabricated from resin-impregnated rayon-mat fabric do not appear to be better over-all core materials for use in sandwich construction than resin-impregnated paper honeycomb cores of equal density, as indicated by this investigation.

INTRODUCTION

In an effort to obtain a strong, lightweight core material suitable for sandwich constructions, several types of honeycomblike structures have been devised. Materials such as paper, glass cloth, and cotton cloth have been used to fabricate honeycomb cores by bonding together resin-impregnated sheets of the corrugated material. Tests of these cores have shown sufficient strength for some sandwich-material applications, but other sheet materials are being investigated in the hope of finding a stronger, more durable honeycomb structure.

The work reported herein was undertaken to determine the mechanical properties of two rayon-mat fabrics as compared with those of other known honeycomb materials, such as resin-impregnated kraft paper.

This work was conducted at the Forest Products Laboratory under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics.

DESCRIPTION OF MATERIALS

Rayon Fabric

Two weights of plain, nonwoven, dense-finish rayon fabrics were received from a commercial source. These materials were similar in appearance and texture and differed only in weight, that of one being 30 pounds and that of the other 45 pounds per 3000 square feet. The directions of the individual fibers in the fabrics were not perfectly random. A preferred direction was noticeable.

Resins

The three resins used in fabricating the honeycomb cores are commercially available and will be designated as: A, pretreatment resin, and B and C, contact resins. Resin A is a high-temperature-setting phenolic-resin adhesive; resin B is a high-temperature-setting acid-catalyzed phenolic resin; and resin C is a high-temperature-setting, low-viscosity, contact-pressure, laminating resin of the polyester type.

Cores

The commercial rayon-mat fabric as received was first treated with resin A, was then corrugated on the Forest Products Laboratory corrugating machine equipped with "A" flute rolls, and was then treated with contact resin B or C. After this the core was assembled. A complete description of the fabrication of the cores is given in reference 1.

Eight blocks of the material were made and tested. Four of them were made of the 30-pound fabric and four of the 45-pound fabric. In one block of each group of four, the preferred direction of the individual fibers was placed perpendicular to the direction of the axes of the cells of the honeycomb; in the other three blocks of each group, the preferred direction of the fibers was placed parallel to the direction of the axes of the cells. Also, one block of each weight of fabric was made with approximately 20 percent of contact resin by weight, while approximately 70 percent of contact resin was used in the other blocks (table 1).

TEST METHODS

In general, the test methods conformed to or were similar to those described in references 2 and 3. All specimens were conditioned to approximate weight equilibrium in a room maintained at 75° F and 65-percent relative humidity, and were weighed and measured prior to testing.

Compression Tests

The compression test specimens were cut from the blocks of the honeycomb material and were approximately 8 inches long in the direction of the axes of the cells, and 2 by $2\frac{1}{2}$ inches in cross section. One-half of the number of specimens cut from each block were tested as cut. The ends of the remaining specimens were set into molding-plaster casts to a depth of approximately 3/8 inch, as illustrated in figure 1. Previous experience in the testing of honeycomb structures indicated that the plaster would prevent localized crushing of the ends of the honeycomb cells in contact with the head of the testing machine. This support of the cell walls approximates that found in a sandwich construction in which the ends of the individual cells of a honeycomb core are bonded to a facing material.

The specimens were tested in the direction of their lengths in a hydraulic testing machine, at a constant rate of head travel of 0.024 inch per minute. Deformations were measured by means of a Marten's mirror-type compressometer of 2-inch gage length. Load-deformation curves were plotted, from which values of modulus of elasticity were obtained. Maximum loads were recorded, and the maximum compressive stresses were computed.

Tension Tests

The tension specimens were 1/2 inch in the direction of the axes of the cells and nominally 1 inch square in cross section. One-inch aluminum cubes were bonded to the ends of the honeycomb cells (cross-sectional faces), and the specimens were loaded through the aluminum cubes in a hydraulic testing machine (fig. 2). The head travel of the machine was maintained at a constant rate of 0.05 inch per minute throughout each test. Ultimate load, type of failure, and percent of core failure were recorded.

Shear Tests

The specimens for the shear tests were 1/2 inch in the direction of the axes of the cells and 2 by 6 inches in cross section. Steel plates were bonded to the ends of the honeycomb cells (cross-sectional faces) in a way similar to the bonding of facings of a finished sandwich panel. The 6-inch dimension was in the tangential direction, that is, parallel to the laminations of the corrugated rayon sheets. These specimens were tested in a hydraulic testing machine, as illustrated in figure 3, at a constant rate of head travel of 0.01 inch per minute. Deformations were measured by means of a dial gage having 0.0001-inch graduations. Load-deformation curves were plotted from which values of modulus of rigidity were obtained. Maximum loads were recorded, and the maximum shear stresses were computed.

Tests for Poisson's Ratio

The specimens tested for the determination of Poisson's ratios were 1/2 inch in the direction of the axes of the cells and 2 by 2 inches in cross section. The test apparatus shown schematically in figure 4 was used for this series of tests, since the apparatus normally used for the testing of wood specimens was not applicable to the testing of honeycomb materials. Poisson's ratios were determined in the TR- and RT-directions, as shown in figure 5, for six of the eight rayon-mat honeycomb cores. A specimen, A (fig. 4), was placed between the support, B, and loading bar, C, on 1/8-inch-diameter rollers so as to permit large deformations to take place within the specimen in the direction of the applied load without appreciable friction between the specimen and the base plate. However, there was a small amount of friction between the specimen and the rollers as the specimen deformed in the direction perpendicular to that of the load. A wire yoke connected the loading pan, E, and the loading bar, and the specimen was loaded by placing the desired number of calibrated weights on the pan. Deformation of the specimen was measured by means of a Tuckerman compressometer of 1-inch gage length. The specimens were loaded twice in each of the directions L and R, with the deformations being recorded for equal increments of load, in the direction of loading on the first run, and perpendicular to the direction of loading on the second run.

PRESENTATION OF DATA

Table 1 is a compilation of the mechanical properties of the resin-impregnated, rayon-mat, honeycomb core materials as determined from the tests described. Each value in the table under "Tension tests" is the average of the results of the tests of five specimens; each value under "Shear tests" is the average of two tests; each value under "Compression tests" is the average of four tests, except that the values for blocks 33 and 36 are the averages of eight tests; and each Poisson's ratio value is the average of two tests. It may be noted that only compression test data are listed for block 30. This block did not have sufficient contact resin to form a good bond between the individual corrugated sheets of rayon, and the material delaminated when an attempt was made to cut the smaller-sized specimens from the block. Some of the strength values for blocks 32 and 35 are not listed, because these blocks were not large enough to provide a sufficient number of specimens for all of the tests required. At the bottom of table 1, the mechanical properties are listed for a 45-pound, resin-impregnated, kraft-paper, honeycomb core material, having a fiber direction perpendicular to the axes of the cells and an apparent specific gravity of 0.1, for comparison with the properties of the rayon-mat cores.

DISCUSSION OF RESULTS

The tensile strength of the 45-pound rayon-mat-fabric honeycomb, with the fiber direction parallel to the direction of the axes of the cells, when impregnated with approximately 70 percent contact resin, was approximately 40 percent greater than that of paper honeycomb of the the same apparent specific gravity having the fiber direction perpendicular to the axes of the cells. The tensile strength of the 30-pound rayon-mat-fabric honeycomb was almost equal to that of the paper honeycomb, while its weight was only 60 percent of that of the paper. As was to be expected, the tensile strength of the cores fabricated with the mat fiber direction parallel to the axes of the cells was almost twice that of the cores with the mat fibers perpendicular to the direction of loading.

The rayon-mat cores were considerably weaker than the paper honeycomb core material in shear strength and modulus of rigidity in the plane perpendicular to the axes of the cells. The values for these properties of the rayon cores were 63 and 43 percent, respectively, of those for th paper cores. It is interesting to note, however, that these properties had slightly higher values when the fiber direction of the rayon mat was perpendicular rather than parallel to the axes of the honeycomb cells.

The compressive strength and modulus of elasticity in compression of the rayon-mat honeycomb, in the direction of the axes of the cells, were the lowest of any of the properties determined when compared with those of honeycomb paper. The strength of the 45-pound rayon was only 43 percent of that of the paper, and was reduced further to about 25 percent when the fiber direction was perpendicular to the axes of the cells. From the data shown in table 1 it appears that the 30-pound rayon had a higher compressive strength when the fiber direction was perpendicular than when it was parallel to the axes of the cells. This, however, would not be true if the cores tested had similar apparent specific gravities, for the core with perpendicular fiber orientation was approximately 30 percent heavier, an indication that much more resin had been applied to this core, and that the core would sustain greater compressive loads.

Figure 6 is a descriptive comparison of the apparent compressive strengths of honeycomb core materials fabricated from chestnut-chip paper, kraft paper, and rayon-mat fabric. The curves shown in this figure were computed by the method presented in reference 4. The points plotted about the bottom curve are from the data given in table 1 for the rayon-mat materials having the fiber direction parallel to the axes of the cells. The equation for these curves is:

$$p_s = c\left(\frac{g_a}{rg - g_a}\right)^{2/3}$$

where

p_s	specific compressive strength of fabric
g_a	apparent specific gravity of honeycomb
r	ratio of the original length of the material to the projected length of the material after corrugation
g	specific gravity of impregnated fabric
c	constant for material

As c might be called the fundamental specific compressive stress, a comparison of the values of c for different core materials will indicate their relative compressive strengths for any given apparent specific gravity. On this basis, the compressive strength of the rayon-mat honeycomb in the direction of the axes of the cells is only 43 and 57 percent of the compressive strength of chestnut-chip and kraft-paper honeycomb core materials, respectively.

The values listed for Poisson's ratios are the average values obtained from two tests of one specimen from each block. Considering the low moduli of elasticity in the R- and T-directions and the small loads applied, the effect of friction between the specimen and the rollers and in the pulley axle may have had some influence on the results obtained from the tests. Values of Poisson's ratio greater than unity in the RT-direction were determined for all but two of the specimens. (See table 1.)

CONCLUDING REMARKS

From tests made to determine some of the strength and elastic properties of honeycomb-type core materials fabricated from resin-impregnated rayon-mat fabrics, the following conclusion can be drawn. Honeycomb core materials fabricated from resin-impregnated rayon-mat fabric do not appear to be better over-all core materials for use in sandwich construction than resin-impregnated paper honeycomb cores of equal density.

Forest Products Laboratory
Madison, Wis., December 21, 1948

REFERENCES

1. Norris, C. B., and Mackin, G. E.: An Investigation of Mechanical Properties of Honeycomb Structures Made of Resin-Impregnated Paper. NACA TN 1529, 1948.

2. Anon: Methods of Test for Determining Strength Properties of Core Material for Sandwich Construction at Normal Temperatures. Rep. No. 1555, Forest Products Lab., U. S. Dept. Agriculture, revised Oct. 1948.

3. Anon: Methods for Conducting Mechanical Tests of Sandwich Construction at Normal Temperatures. Rep. No. 1556, Forest Products Lab., U. S. Dept. Agriculture, revised Oct. 1948.

4. Norris, Charles B.: An Analysis of the Compressive Strength of Honeycomb Cores for Sandwich Constructions. NACA TN 1251, 1947.

TABLE 1

MECHANICAL PROPERTIES OF RESIN-IMPREGNATED RAYON-MAT HONEYCOMB-TYPE CORE MATERIAL

Block	Rayon-mat weight (lb)	Resin pretreatment (percent)	Contact resin (percent)	Apparent specific gravity	Tension tests		Shear tests			Compression tests				Tests for Poisson's ratio			
										Free ends		Supported ends					
					Strength (psi)	Core failure (percent)	Strength (psi)	Modulus of rigidity (psi)	Core failure (percent)	Apparent strength (psi)	Modulus of elasticity (psi)	Apparent strength (psi)	Modulus of elasticity (psi)	Modulus of elasticity in T-direction (psi)	Modulus of elasticity in R-direction (psi)	Poisson's ratio in TR-direction	Poisson's ratio in RT-direction
a29	45	19	16.0	0.038	325	100	56	2,400	100	64	b9,990	66	------	8.2	6.1	0.51	0.77
a30	30	14	21.0	.031	---	---	---	------	---	34	b6,740	34	------	----	----	----	----
a31	45	19	69.0	.100	487	100	160	5,360	100	203	30,750	211	32,800	40.7	71.9	.65	1.67
a32	45	19	66.0	.096	---	---	---	------	---	167	26,720	162	28,940	----	----	----	----
c33	45	19	66.0	.091	267	100	170	7,610	100	118	11,850	124	11,750	10.6	69.0	.92	1.02
a34	30	14	67.5	.062	326	100	106	4,830	100	65	19,210	81	17,440	5.6	13.4	.46	1.51
a35	30	14	67.5	.061	---	---	---	------	---	111	13,130	83	14,140	6.9	10.7	.47	.98
c36	30	14	70.5	.081	184	100	119	5,720	100	163	10,970	173	11,950	20.5	83.3	.66	1.26
Paper honeycomb[c]				.100	340	---	270	17,700	---	450	72,500	---	------	110.0	100.0	----	----

[a]Fiber direction of material parallel to axes of cells.
[b]Deformations measured between heads of testing machine.
[c]Fiber direction of material perpendicular to axes of cells.

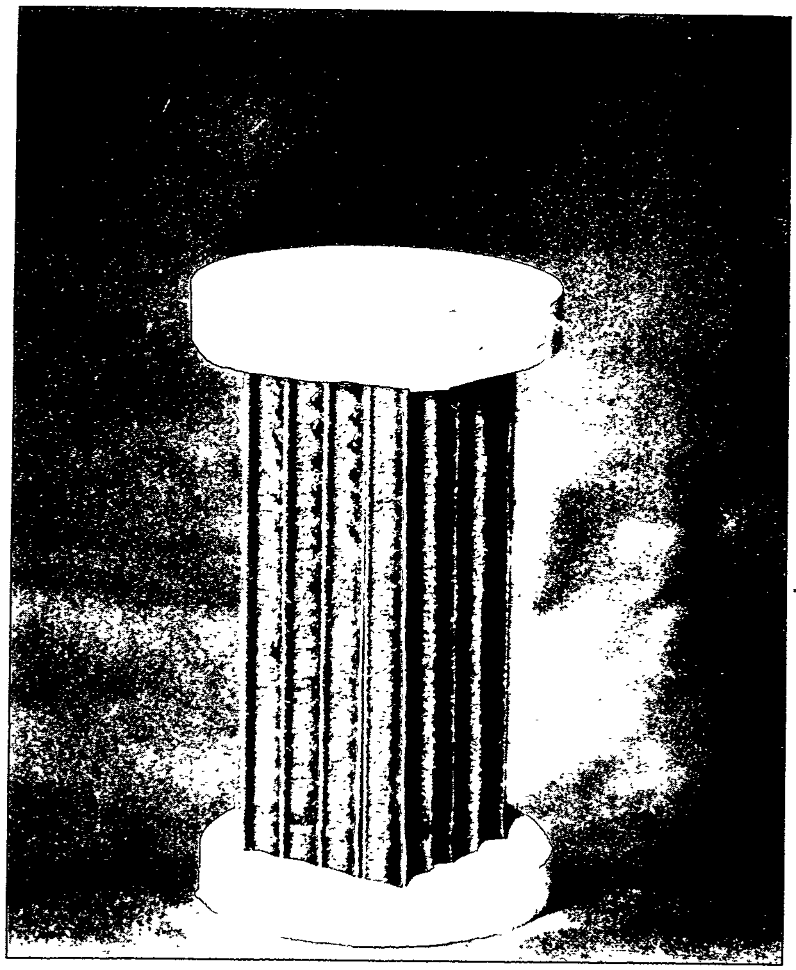

Figure 1.- Compression test specimen of honeycomb core material with ends supported by molding plaster.

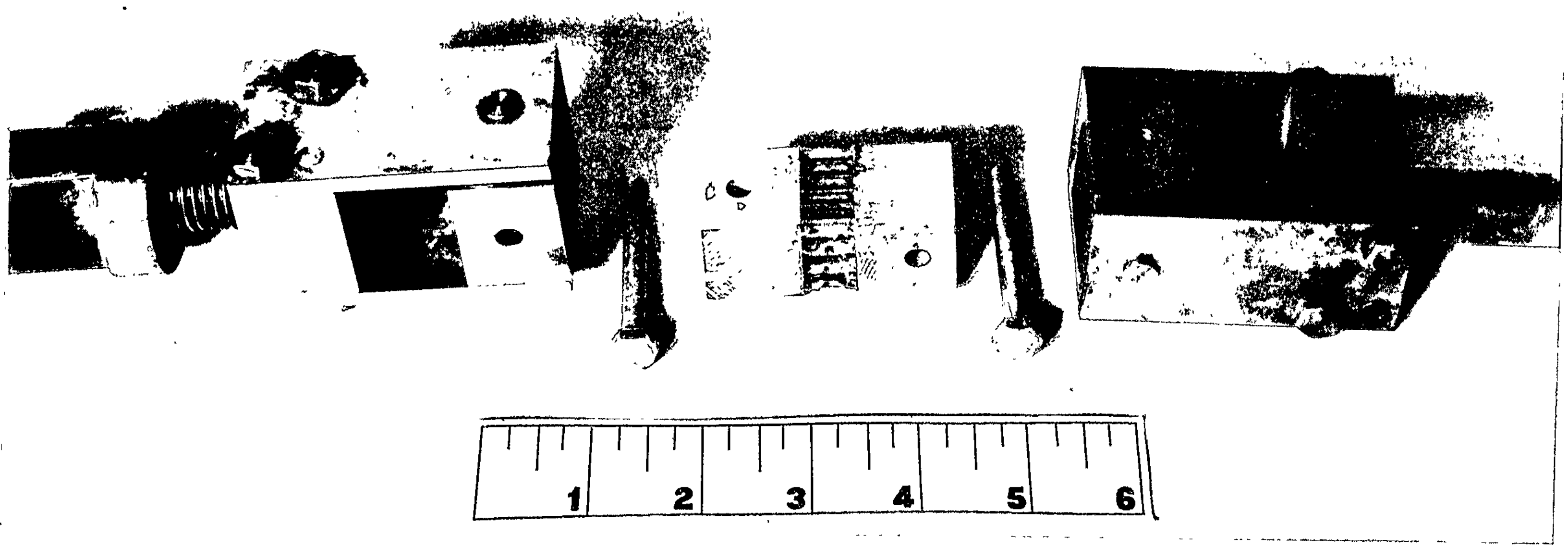

Figure 2.- Tensile test specimen of honeycomb core material showing aluminum cubes and grips for applying load to specimen.

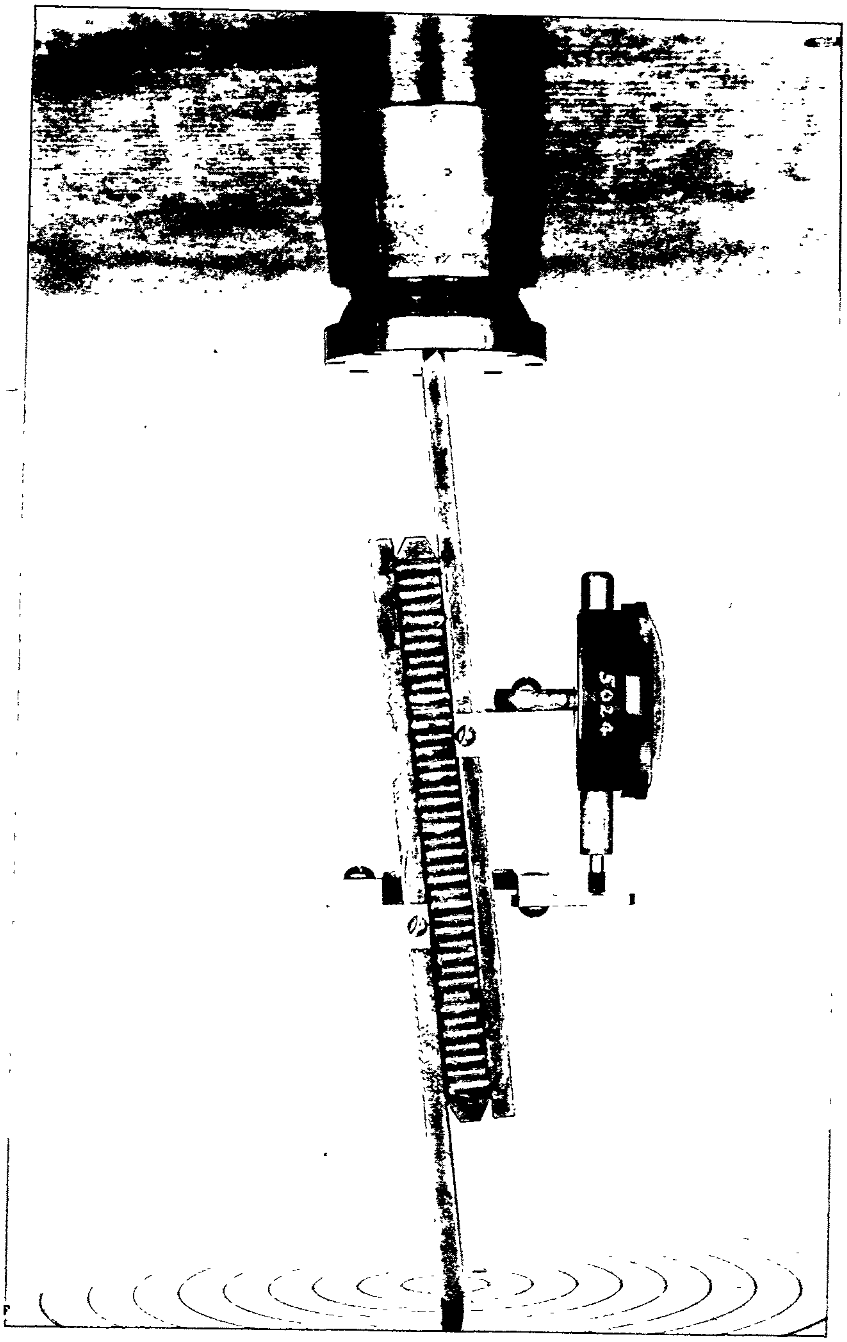

Figure 3.- Shear test specimen of honeycomb core material showing apparatus for measuring shear deformations.

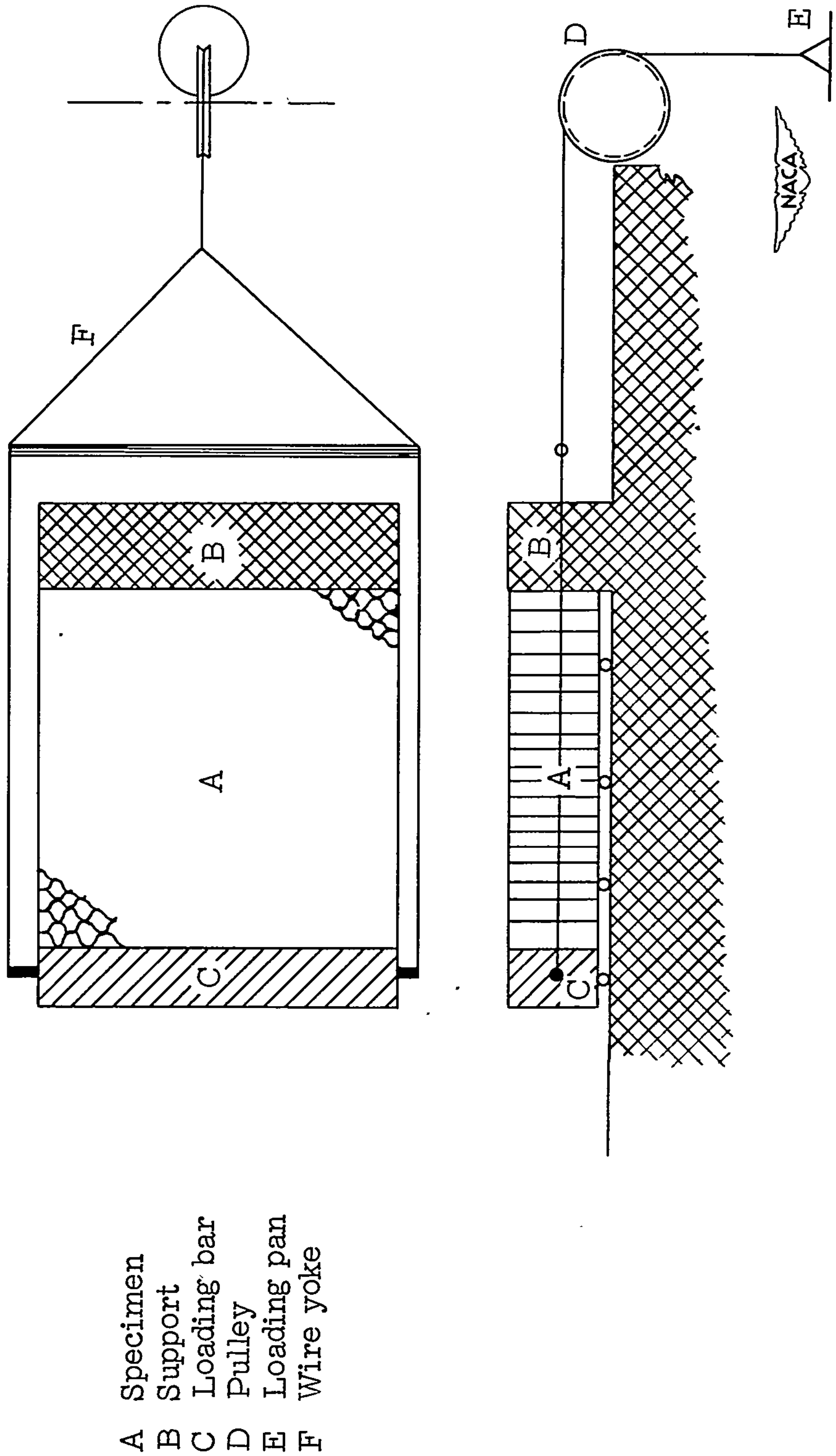

Figure 4.- Schematic diagram of test apparatus used for determining Poisson's ratio for 1/2-inch by 2-inch-square rayon-mat honeycomb specimens.

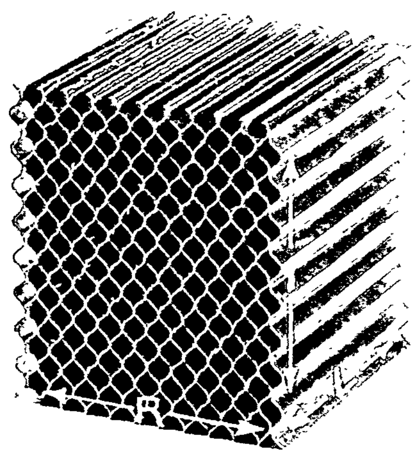

Figure 5.- Cross-sectional view of a honeycomb-type core material showing directional notation used.

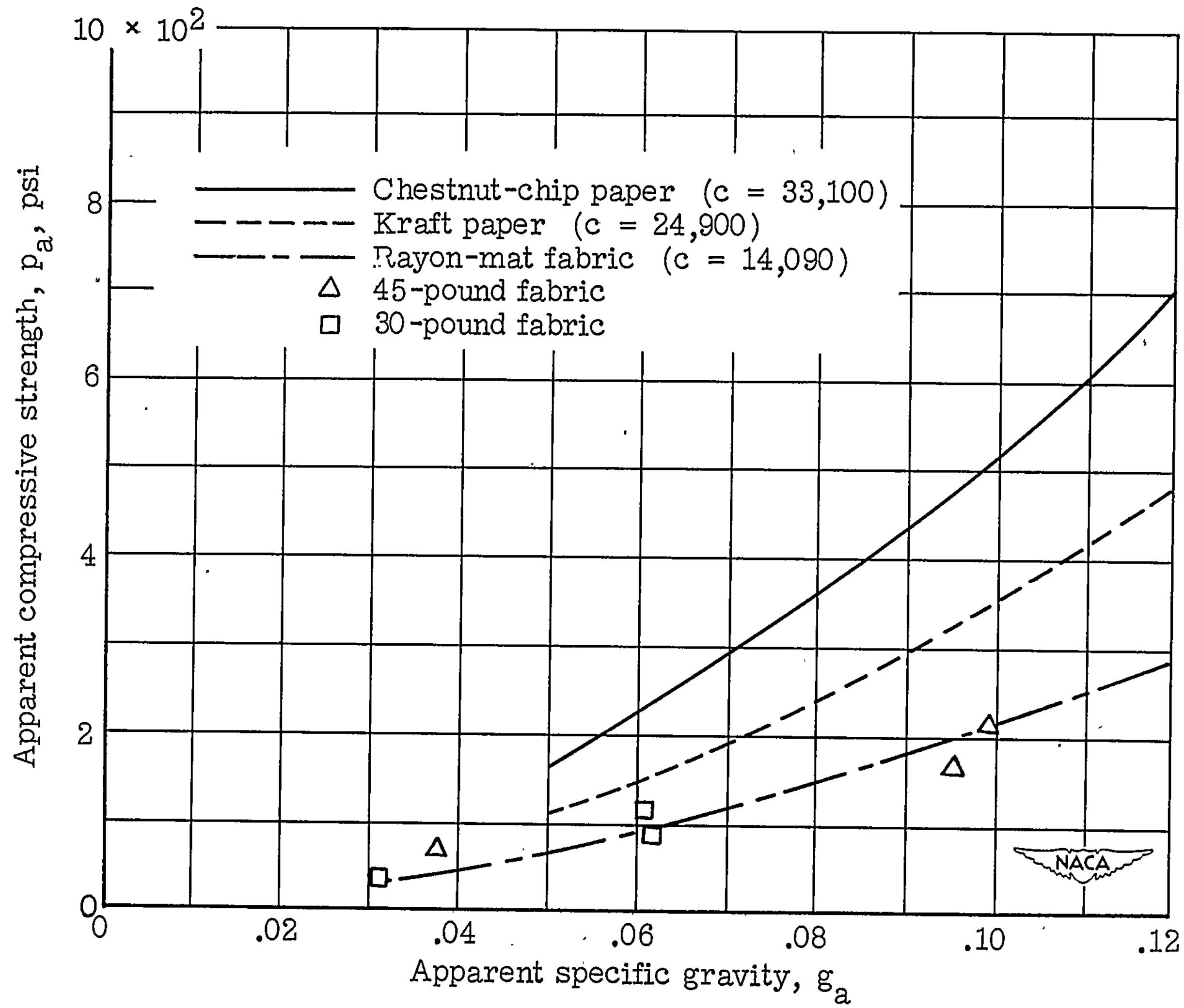

Figure 6.- Curves of compressive strength against specific gravity for rayon-mat, chesnut-chip, and kraft-paper honeycomb core materials. Curves computed by using equation (11), reference 4. Points around bottom curve taken from table 1. $p_a = p_s g_a$.

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